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THE DEATH CAMAS SPECIES, ZYGADENUS PANICULATUS AND Z. ELEGANS, AS POISONOUS PLANTS.

BY: C. Dwight Marsh

U.S.D.A. Bul. 1012 April 17, 1922

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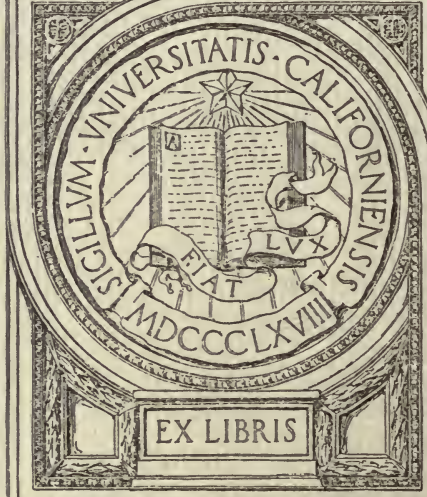

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UNITED STATES DEPARTMENT OF AGRICULTURE

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THE DEATH CAMAS SPECIES, ZYGADENUS PANICULATUS AND Z. ELEGANS, AS POISONOUS PLANTS.

By C. Dwight Marsh, *Physiologist in Charge of Investigations of Stock Poisoning by Plants*, and A. B. Clawson, *Physiologist, Pathological Division.*

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PURPOSE AND SCOPE OF PAPER.

In Bulletin 125, United States Department of Agriculture, page 35, the following statement was made with regard to the comparative toxicity of different species of Zygadenus:[1]

In the course of the experiments four species of Zygadenus were used—*Z. venenosus*, *Z. elegans*, *Z. paniculatus*, and *Z. coloradensis*—by far the greater part of the work being done with *Z. venenosus*. The number of experiments with *Z. elegans* and *Z. paniculatus* was very small, and the material, especially in the case of *Z. paniculatus*, had been shipped a long distance, so that there was some question of the water content of the plant. Apparently, however, *Z. elegans* and *Z. paniculatus* do not differ materially in toxicity from *Z. venenosus*. *Z. coloradensis*, however, produced no toxic effects whatever, with the exception of slight symptoms in one sheep, although the plant was fed in quantities several times as great as the toxic dose of *Z. venenosus*.

It is evident that in the feeding of cattle with *Z. coloradensis* at Mount Carbon in 1909, the results of which are given in Table I, the quantities fed were too small to produce results, even if the plants were as poisonous as *Z. venenosus*. In the experiment of 1910, however, a large quantity was fed, and sufficiently large quantities in single days to produce symptoms of poisoning if the plant were as toxic as *Z. venenosus*.

Most of the work reported in Bulletin 125 was on the species of Zygadenus growing in the Yellowstone Valley, Montana, which

[1] Zygadenus, or Death Camas, by C. Dwight Marsh, A. B. Clawson, and Hadleigh Marsh, Bulletin 125, United States Department of Agriculture, 1915.

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at that time was determined by systematic botanists as *Z. venenosus*. Later systematic work has shown that the species used was not the true venenosus, but was *Z. gramineus*. Of the other species used, *Z. elegans* and *Z. coloradensis* are so closely allied that they are considered by many botanists as not specifically distinct. There is no question, however, of the specific distinction between *Z. gramineus*, *Z. elegans*, and *Z. paniculatus*. From further work it seemed probable that there was a much greater difference in toxicity of the species than was apparent at the time Bulletin 125 was published, and it became a matter of considerable importance to determine the comparative toxicity of the different forms.

All these species are so closely allied that they are not likely to be separated by anyone who has not a fairly good knowledge of botany. It follows, of course, that ordinarily all these forms are grouped under the term "death camas" without perception of the difference between the species. It is a matter of much scientific and practical interest to know how they differ.

Z. paniculatus is the most widely distributed and is the most common form of death camas in the intermountain region and in part of the western slope. *Z. elegans* is not so abundant but is the common species on the higher mountain ranges of the West. Both *Z. elegans* and *Z. paniculatus* grow in considerable quantity in the neighborhood of the Salina Experiment Station, Utah, where a somewhat extended study of the plants has been made. The proof that these species are either more or less toxic than *Z. gramineus*, which grows in Montana, would be of very great practical importance to the stockmen who use the ranges where these plants are found.

The experimental work was conducted on the same general lines as the work in Montana, and the results have proved to be of considerable importance. Still further work is necessary on the species of this genus, but the results obtained regarding these two species are definite and conclusive. All the work here reported was done on plant material collected in Utah. Inasmuch, however, as experience with poisonous plants indicates that difference in locality has little effect on the degree of toxicity, the conclusions reached here undoubtedly will apply equally well to these species wherever they may be found. It may be added that *Zygadenus intermedius*, on which work has been done by other authors, is considered by systematists as being identical with *Zygadenus gramineus*.

ZYGADENUS PANICULATUS.

DESCRIPTION AND DISTRIBUTION OF THE PLANT.[2]

Zygadenus paniculatus, shown in Plate I, is an erect perennial herb with leafy stems arising from fibrous-coated bulbs. The linear leaves

[2] The description of *Z. paniculatus* and its distribution was prepared by W. W. Eggleston, of the Bureau of Plant Industry. Mr. Eggleston has made a detailed study of the genus Zygadenus.

are scythe-shaped, all sheathing, roughish on both sides, rather thick, 6 to 12 inches long, and one-third to two-thirds of an inch wide. The stems are stout, erect, and 1 to 2½ feet high. The flowers are in panicled racemes, and consist of six segments with membranous bracts; the upper segments are deltoid, acute, or acuminate, with a short claw and glands at base not definitely margined. The flower segments are one-sixth to one-fourth of an inch long and are free from the 3-celled ovary. The ovary is cylindrical and one-half to 1 inch long. The stamens are raised above the flower segments.

This plant is largely confined to the Great Basin. (Fig. 1.) Its known range is from the British Columbia line in the Cascades south, in Washington, along the eastern side of the Cascade Range to northwestern California, where for a distance it crosses to the western side of the Sierra Nevádas. It follows the eastern slope of the Sierra Nevada Mountains to the southern extremity of Nevada. It ranges eastward across southern Washington and central Idaho to western Montana, thence across southwestern Wyoming to northeastern New Mexico and northern Arizona. It ascends on the British Columbia line to about 7,000 feet and in the Wasatch Mountains to about 8,500 feet. In California it is found above 2,700 feet. Its best habitat is the dry gravelly ridges of the juniper-piñon-oak belt.

FIG. 1.—Distribution of *Zygadenus paniculatus*.

Because of the wide range of conditions under which the plant grows, its time of flowering varies. It is said to blossom in California from April to June. Near the Salina Experiment Station, Utah, where it grows at an altitude of more than 8,000 feet, it does not blossom until June and is in seed the last of the month.

EXPERIMENTAL FEEDING.

In 1919, 1920, and 1921, 7 experimental feedings of *Z. paniculatus* were made on cattle and 44 on sheep. Table 1 gives a summary of these experiments.

TABLE 1.—*Summary of feeding experiments with Zygadenus paniculatus, 1919, 1920, and 1921.*

Animal.		Date of feeding.	Method of feeding.	Part of plant used.	Weight of plant estimated as green plant for 100 pounds of animal.	Result.	Place and date of plant collection.	Remarks.
Designation.	Weight.							
Sheep Nos:	*Pounds.*	*1919.*			*Pounds.*			
519	59	June 10	Balling gun.	Leaves and bulbs	0.627	Not sick	Ephraim, Utah, June 9, 1919.	10 per cent allowed for loss by evaporation.
528	75	June 11	do	do	1.175	Very sick	do	20 per cent allowed for loss by evaporation; probably more should be allowed.
530	80	June 13	do	Leaves, stems, and buds	1.096	Sick	Flat Top, near Salina, June 12, 1919.	10 per cent allowed for loss by evaporation.
520	86	June 13 to 15	Fed in hay.	do	(1)	Not sick	do	Refused to eat.
555	92	June 14	Balling gun.	do	1.261	Sick	do	20 per cent allowed for loss by evaporation.
540	86	June 16	do	Leaves, stems, buds, and bulbs	1.761	do	do	40 per cent allowed for loss by evaporation. Vomited part of material fed.
Cattle No:								
826	386	June 21	Fed in hay.	Leaves, stems, and immature flowers.	1.295	do	Flat Top, June 19, 1919.	
Sheep Nos:		*1920.*						
564	77.5	June 9 to 15	do	do	.284	do	Flat Top, June 8 and 11, 1920.	
579	69	June 15 to 18	do	do	(1)		Flat Top, June 11, 1920.	
578	90.5	June 15 to 19	do	do	1.450±	Sick	do	
581	67	June 18	Balling gun.	Leaves, stems, flowers, and young fruit.	1.010	Not sick	Bear Valley, Utah, June 16, 1920.	
521	103	June 20 to 23	Fed in hay.	Leaves, stems, and old flowers	.728	do	Flat Top, June 19, 1920.	
554	115	do	do	do	1.304	do	do	
500	135.5	June 20 to 26	do	do	.738±	do	do	
583	83	June 21	Balling gun.	Leaves, stems, flowers, and young fruit.	1.505	Sick	Bear Valley, Utah, June 16, 1920.	
586	132.5	June 22 and 23	Fed in hay.	Leaves, stems, and old flowers	(2)		Flat Top, June 19, 1920.	
590	86	June 23	Balling gun.	Leaves, stems, flowers, and young fruit.	2.077	Sick	Bear Valley, June 16, 1920.	
591	100.5	June 25 to 28	Fed in hay.	Leaves, stems, and old flowers	(2)		Flat Top, June 24, 1920.	

592	123	do	do	do	(2)		Flat Top, June 19 and 24, 1920.	
594	95	June 25 to 29	do	do	2.105±	Not sick	Flat Top, June 24, 1920.	
593	68.5	June 26	Balling gun	do	1.323	Sick	do	
599	93	June 29	do	Leaves, stems, and young fruit	1.543	Symptoms	Flat Top, June 28, 1920.	
598	100.5	June 30 to July 3.	Fed in hay	do	.75±	Not sick	do	
602	79.5	July 1	Balling gun	do	1.764	Sick	Flat Top, June 30, 1920.	
604	120	July 2 to 4	Fed in hay	do	.833±	Not sick	do	
605	101.25	July 3	Balling gun	do	1.984	Sick	do	
609	83	July 8	do	Leaves and stems	1.984	do	Flat Top, July 7, 1920.	Fruits had been removed.
569	92	July 9	do	Fruit heads	.661	Very sick	do	
575	69.5	July 10	do	Leaves and stems	2.862	Sick	do	
607	103	August 4	do	Fruit heads nearly fully developed	.358	Not sick	do	
609	87	August 5	do	do	.620	Sick	do	
583	102	August 26	do	Seed (ripe and dry)	3.070	Very sick	Between Cove Fort and Beaver, Utah, July 23, 1920.	Figured as dry seed.
Cattle Nos:								
874	325	June 12 and 13	Fed in hay	Leaves, stems, and flowers	.468	Weakness	Flat Top, June 11, 1920.	Loss in drying about 82 per cent. About 1.5 pounds eaten by animal.
867	379	June 15 to 20	do	do	.659	Salivation and weakness.	do	Sick after eating 0.264 pound in 1 day. Symptoms continued for 6 days.
870	382	June 20 to 26	do	Leaves, stems, and old flowers	5.759	Weakness	Flat Top, June 19 and 24, 1920.	Symptoms after eating about 0.8 pounds of Zygadenus.
861	420	July 3 and 4	do	Leaves, stems, and young fruit	.738	Salivation	Flat Top, June 30, 1920.	Not all eaten when symptoms appeared.
863	496	do	do	do	1.109	Vomiting	do	Sick after eating about 0.7 pound.
Sheep Nos:		1921.						
582	108.5	July 13	Balling gun	Leaves, stems, and flowers	1.323	Symptoms	Flat Top, June 15, 1921	Dry plant fed, estimated as green.
612	98	July 18	do	do	1.323	Sick	Flat Top, June 25, 1920	Do.
617	118	July 19	do	do	2	do	do	Do.
628	109.5	August 2	do	do	2.1	do	do	Do.
629	115	August 4	do	do	2.3	do	do	Do.
644	90.5	August 15	do	do	2.5	Death	do	Death perhaps due to pneumonia.
647	88	August 22	do	do	2.5	Very sick	do	Dry plant fed, estimated as green.

[1] None eaten.

[2] Little, if any, eaten.

[3] Dry weight.

TYPICAL CASE OF SHEEP 602.

Sheep 602 was a yearling ewe, weighing at the time of the experiment 71.5 pounds. It was taken into the corrals on June 29, 1920, and kept under observation until the experimental feeding was undertaken, on July 1.

On July 1, at 11.15 a. m., the animal was given by balling gun 1.764 pounds, per 100 pounds of animal, of leaves, stems, and young fruit of *Z. paniculatus*. At 2.30 p. m. the animal was frothing at the mouth, and in walking reeled from side to side. At 2.35 p. m. the weakness was most pronounced in the hind legs. This weakness gradually increased and at 7.40 p. m. the animal, in walking, not only staggered but dragged the hind feet. The condition remained the same during the evening. The next day, July 2, at 6.38 a. m., the animal was still frothing at the mouth and apparently somewhat nauseated, although it seemed somewhat stronger than during the preceding evening. During the day its condition did not change materially. It was quiet and depressed and weak, but not very sick. The last observation of the day was made at 4.15 p. m.

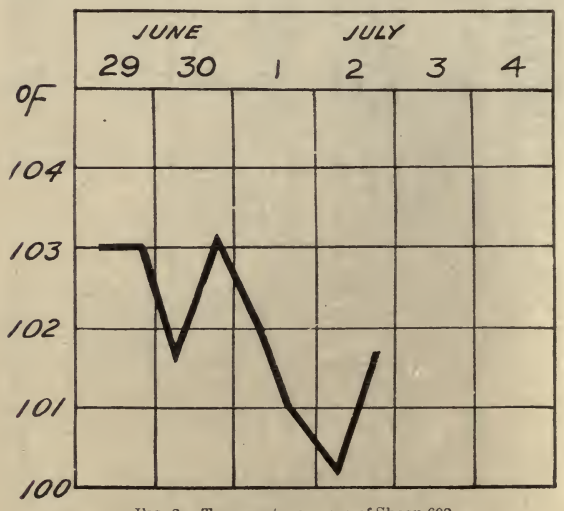

FIG. 2.—Temperature curve of Sheep 602.

On the morning of July 3 the animal seemed to be entirely recovered. The temperature curve is shown in text figure 2. While there were variations in the pulse and respiration, the changes were not significant.

Sheep 602 may be considered as a fair type of animals which are not very sick.

TYPICAL CASE OF SHEEP 569.

Sheep 569 was a 2-year-old wether, weighing 85.5 pounds at the time of the experiment. It was taken from the pasture into the corrals on the morning of July 8, 1920. At this time the temperature was 103° F., pulse 88, respiration 32. The sheep was observed again at night, and on the morning of July 9. At 9.35 a. m., July 9, the temperature was 103° F., pulse 96, respiration 24. At 2 p. m. the animal was given by balling gun 0.661 pound, per hundredweight of animal, of fruit heads of *Z. paniculatus*. At 4.37 p. m., the animal

was found to be very sick and in some pain, with irregular respiration. There was a pause after the inspiration, followed by a somewhat forcible expiration. The animal was weak and soon lay down. At 4.46 p. m., the temperature was 98.4° F., pulse 96, respiration 28. The pulse was fairly strong and regular. The respiration continued as before. At this time the sheep was frothing at the mouth, was much depressed, and showed weakness in the hind legs. A little later the respiration was found to be very rapid, being approximately 200. At 5.32 p. m., the animal was down, evidently had been struggling, and was unable to rise. Plate II, figure 1, shows the position the animal assumed at this time. From then until about 6 p. m., its condition remained practically unchanged. The temperature at 5.34 p. m. was 99.4° F., and the respiration 40. Most of the time the animal was fairly quiet but unable to rise. At 5.57 p. m., it was able to get up on its feet, although still very weak. Plate II, figure 2, shows the attitude assumed at this time. The weakness seemed most pronounced in the forelegs. About 6 p. m. it went down because of weakness and almost immediately got up again, the weakness, as before, being most pronounced in the forelegs. From 7.20 until 11.13 p. m. it was lying down quietly, most of the time apparently unable to rise. At 11.13 p. m. it was breathing heavily and rather noisily at the rate of 20 a minute.

On July 10, at 6.30 a. m., it was in about the same position as during the preceding evening. Plate II, figure 3, shows its attitude at this time. At 8 a. m., while still lying down, it was found to have moved across the pen. At 8.40 a. m., when disturbed it attempted to get upon its feet, but was unable to lift the body on the forelegs. At this time the temperature was 99.3° F., pulse 112, and respiration 24. These observations were taken just following an attempt to rise. After lying quietly, the pulse was about 100. The sheep at this time was in a semicomatose condition, with the eyes half closed, but roused if approached. The condition remained much the same during the rest of the day, and the evening. The picture Plate II, figure 4, taken at 2.50 p. m., shows very well the condition of the animal. The coma was very pronounced during this period. At midnight the animal commenced to kick and went into a position of opisthotonos, at the same time gasping. Following these spasmodic movements, which could hardly be called convulsions, its mouth was opened during the expirations.

On July 11, at 7.30 a. m., it was found lying much as at midnight, but breathing more easily. At 10.35 a. m., the temperature was 99.7° F., pulse 120, respiration 44. The pulse was weak and variable, and the respiration somewhat labored. A little later the respiration was too fast to count. The condition remained the same during the forenoon and evening. At 4.15 p. m. and at 5 p. m., it was

given hypodermically 5 c. c. of gin, which seemed to have an immediate but temporary effect in strengthening the action of the pulse. No change was noticed during the evening, except that at 11.25 p. m., the pulse was found to be distinctly stronger than earlier in the evening.

On July 12, at 8.30 a. m., the temperature was 100.6° F., pulse 116, and respiration 16. The pulse was very weak, while the respiration was deep and regular. The animal appeared brighter than during the preceding evening, but was still lying down. At 10.45 a. m., the sheep was raised up, and drank 3 or 4 quarts of water. It was able to hold itself up for two or three minutes, but soon lay down again. The animal drank again at 11.35 a. m., and attempted to get up on its feet, but was unable to do so. At 3.30 p. m., it was raised up and drank more water. The temperature at this time was 100.6° F., pulse 120, and respiration 12. At 5 p. m., it was offered some green forage, and ate readily. The condition continued unchanged during the evening.

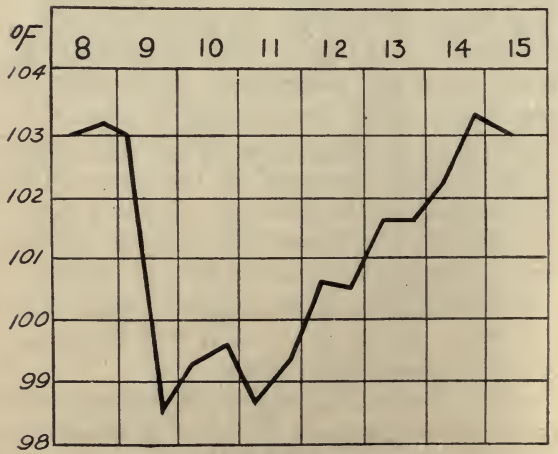

FIG. 3.—Temperature curve of Sheep 509.

On July 13, at 7 a. m., the sheep was raised up on its feet and held, and then it became able to stand alone. It was unable, however, to walk without falling. The legs of the left side seemed weaker than those of the right. This perhaps was due to the fact that during the period it was lying down it lay upon the left side. At 4.11 p. m., the temperature was 101.6° F., pulse 120, respiration 164. The pulse was fairly strong and regular. The respiration was short but regular. At this time the animal was on its feet although still very weak. It was able to walk out into a large corral to drink with the other sheep.

During the day, July 14, the temperature of the animal was higher, being 103.3° F. at 4.35 p. m. The pulse was strong and regular and the respiration became more normal. The sheep was quite strong and able to get about and eat.

On the morning of July 15 the animal seemed to have entirely recovered, and was turned into the pasture with the other sheep. Text figure 3 shows the curve of temperature during the illness of the animal.

ZYGADENUS PANICULATUS. PLANT WITH BULB AND FLOWERS.

FIG. 1.—SHEEP 569 AT 5.32 P. M. JULY 9, WHEN POISONED BY ZYGADENUS PANICULATUS,

FIG. 2.—SHEEP 569 AT 5.57 P. M. JULY 9, ABLE TO STAND, BUT VERY WEAK.

FIG. 3.—SHEEP 569 AT 6.30 A. M. JULY 10, SHOWING EXTREME WEAKNESS.

FIG. 4.—SHEEP 569 AT 2.50 P. M. JULY 10, IN CONDITION OF COMA.

FIG. 5.—CATTLE 863 POISONED BY ZYGADENUS PANICULATUS, IN ACT OF VOMITING.

FIG. 6.—HORSE 137 POISONED BY ZYGADENUS PANICULATUS, THE ATTITUDE SHOWING EXTREME DEPRESSION AND DISCOMFORT.

TYPICAL CASE OF CATTLE 863.

Cattle 863 was a steer in good condition, weighing 457 pounds at the beginning of the experimental feeding. It was brought into the corrals on the afternoon of June 30, 1920, and received no feed before the experimental feeding of *Z. paniculatus* was commenced. On July 3, at 9.50 a. m., it was fed leaves, stems, and young fruit of *Z. paniculatus*, and received another feed at 5.15 p. m. the same day. At 9.10 a. m., July 4, it had eaten of the material 1.109 pounds per hundredweight of animal, and refused to eat more. At this time there were no definite symptoms of toxic effect except the refusal to eat. At 5.12 p. m. it was found much salivated and commenced to vomit. This vomiting continued at frequent intervals for about one hour. Plate II, figure 5, shows the animal in the act of vomiting. No further symptoms were noted except the rather unusually low temperature of 99.9° F. at 7.25 a. m., July 5. At this time the general appearance of the animal was good, and it was turned into the pasture as practically recovered. Text figure 4 shows the curve of temperature, indicating a depression as in the other cases.

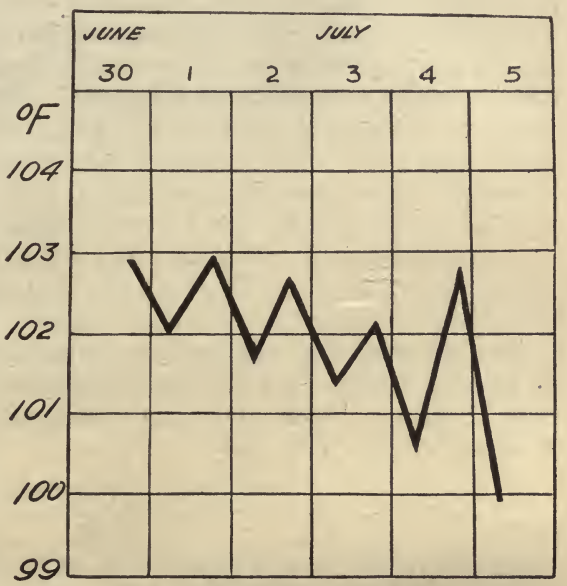

FIG. 4.—Temperature curve of Cattle 863.

ACCIDENTAL CASE OF HORSE 137.

No experiments in feeding the plant to horses were made. An accidental case, however, occurred which was of considerable interest and should perhaps be recorded, since little definite evidence has ever been obtained regarding the effects of Zygadenus upon this class of animals.

Horse 137 was one of the saddle horses used at the station. On July 6, 1920, at 8.15 a. m., it was noticed that this animal was much depressed and salivated, and saliva scattered about the corral showed that this condition of salivation had continued for some time. While this animal was a so-called gentle horse, it never readily per-

mitted itself to be bridled or handled in any way, except when penned up at one corner of the corral. On this morning it could be approached easily and did not object to handling. The respiration was faster than normal, and at intervals retching was observed. In searching for the cause of the illness it was found that the horse had eaten some of a mixture of *Z. paniculatus* and hay that had been thrown into the corral. It was impossible to tell how much he had eaten, so that there was no means of telling what the dosage of the plant had been. The animal showed some abdominal discomfort, and at 9.30 a. m. he was pawing the ground in a manner that indicated some pain. His respiration was about 60 a minute. During the forenoon this condition continued, with prolonged spells of retching, succeeded by profuse salivation. The animal did not stagger or show any unusual weakness. This condition continued during the forenoon and part of the afternoon, but by 4.30 p. m. he had practically recovered.

As the horse was sick when first seen in the morning it was impossible to tell how long the illness continued, but it must have been at least six hours and perhaps somewhat longer. The case is interesting because the symptoms were entirely comparable with those exhibited by sheep and cattle, but did not continue to the stage of weakness. Plate II, figure 6, shows the attitude which the horse assumed during the acute stage of the illness.

DISCUSSION AND RESULTS.

SYMPTOMS.

Salivation.—Salivation appeared in all the cases observed during 1919 and 1921, and was the most distinctive symptom. It occurred in 1920 in 3 of the 5 cattle cases, and in 11 of the 13 sheep cases. Salivation in most cases is the first definite evidence of the effect of the plant. This, of course, can not be considered as an especial characteristic of Zygadenus poisoning, because it occurs in a great many forms of intoxication from plants.

Nausea.—Nausea was exhibited in all the cases in 1919. It was common in the experimental animals of 1920 and 1921, but did not appear in all cases, probably because the sickness was not always very pronounced. Sometimes it was indicated only by regurgitation. In one of the cattle and six of the sheep it resulted in vomiting.

Weakness.—Muscular weakness occurred in 4 of the 5 cases of 1919, in 3 of the 13 sheep, and 2 of the 5 cattle in 1920, and in 6 of the sheep in 1921. In all but one of the cases this weakness was most pronounced in the hind legs and resulted in a characteristic staggering gait. In Sheep 569, which was very sick, and in Sheep 641, which died, this weakness was so pronounced that they were unable to stand. In Sheep 583 and Cattle 784 weakness was the only symptom noted except a depression in temperature. This is well shown in Plate II, figures 1 to 4, in the case of Sheep 569.

Temperature.—In the experimental work of 1919, Cattle 826 was the only case in cattle that showed a depression of temperature. Of the 4 sheep, 3 had a low temperature. In 1920, the 5 head of cattle exhibited a lowered temperature, and of the 13 sheep all but 2 showed the same effect of the plant. In 1921, 4 of the 6 sheep had a lower temperature. This condition of temperature was distinct, but ordinarily the temperature was not very low. The lowest was 98.4° F., which was noted in two cases. One observation of 98.8° F. was made, two of 99° F., and one of 99.6° F. More commonly the temperature did not go below 100° F. and could not be considered as distinctly subnormal. There was, nevertheless, in most cases, a definite lowering of temperature. This is shown in the temperature curves of Sheep 602, Sheep 569, and less markedly in Cattle 863. In the case of Sheep 569 a number of temperatures were recorded besides those of morning and night shown in the diagram, but these additional observations did not alter the character of the curve.

In the work carried on at Greycliff, Mont., on the Zygadenus which is stated in Bulletin 125 to be *Z. venenosus*, and which we are now informed was *Z. gramineus*, it was noted that a depression in temperature sometimes appeared when no other symptoms were seen. It was questioned whether the same phenomena might not occur in the cases receiving *Z. paniculatus*. The only case of this character was Sheep 594, which in 5 days, receiving 2.105 pounds, had no noted symptoms except a lowering of temperature.

In the discussion of the Montana work, in Bulletin 125, the statement was made that a low temperature could hardly be considered as diagnostic of Zygadenus poisoning. The additional work which has been carried on with *Z. paniculatus* shows that while one or a few observations are not diagnostic, if a fairly complete record is made after the feeding of the plant to the animal, this record when plotted is pretty certain to indicate whether any toxic effect has been produced.

Pulse.—The pulse rate in the sick sheep varied from 52 to 220. The rate of 220 was shown by Sheep 644, which had pneumonia. In the sick cattle it varied from 48 to 210. This latter figure, however, was observed in an excited animal before the feeding of the plant. The highest rate after the feeding of the plant was 84. In 2 or 3 of the sheep the pulse rate was slightly higher during the depression of temperature, but in most cases the curve of the pulse followed rather closely the curve of temperature, being low when the temperature was low and rapid when the temperature was high. In some cases it was weak and in some intermittent.

Respiration.—There was some irregularity in respiration, but in general the rate of respiration varied, much like that of the pulse. It was noted in Bulletin 125, in regard to *Z. gramineus*, that there

was a very high rate in the acute stages of the sickness. That this symptom did not appear in the *Z. paniculatus* cases may be explained by the fact that most of the animals were not very sick; that is, the sickness could not be considered as acute at any time. It did occur, however, in Sheep 569, which was very sick. This animal, too, as well as Sheep 644 and 647, exhibited labored breathing. It may be remarked, in this connection, that under normal conditions there is frequently great variation in the respiration of sheep; under excitement the rate may be temporarily very high.

Other symptoms.—Some of the animals groaned and gnashed their teeth during the sickness, and Sheep 569 and Sheep 647 went into a condition of coma. Coma is also a frequent symptom in the animals made very sick by *Z. gramineus*, as shown in Bulletin 125.

In general, the symptoms were practically identical with those seen in *Z. gramineus* cases, but less pronounced, because of the smaller toxicity of *Z. paniculatus* as compared with *Z. gramineus*.

DURATION OF SYMPTOMS.

The following table shows the time that elapsed between the first and last observed symptoms. It should be noted that this probably does not indicate accurately the entire time during which the animals were sick, because in many cases the sickness persisted for a greater or less time after the last note was made.

TABLE 2.—*Duration of symptoms.*

Animal.	Method of feeding.	Time sick.	Animal.	Method of feeding.	Time sick.
1919.			1919		
Sheep Nos.:			Cattle No.:		
528	Balling gun	67 hours 5 minutes. ±	826	Fed in hay	Do.
530	do	20 hours 33 minutes ±			
555	do	27 hours 40 minutes ±	1920.		
540	do	19 hours 8 minutes. ±	Cattle Nos.:		
			874	do	One observation.
1920.			867	do	96 hours.
Sheep Nos.:			870	do	60 hours.
528	do	67 hours 5 minutes.	861	do	Salivated; one observation.
530	do	20 hours 33 minutes.			
555	do	27 hours 40 minutes.	863	do	½ hour.
540	do	19 hours 8 minutes.			
564	Fed in hay	24 hours.	1921.		
578	do	Do.	Sheep Nos.:		
583	Balling gun	7 hours.	582	Balling gun	One observation.
590	do	36 hours.	612	do	16 hours 18 minutes.
593	do	3 hours.	617	do	23 hours 33 minutes.
599	do	Do.	628	do	42 hours 50 minutes.
602	do	26 hours.	629	do	49 hours 16 minutes.
605	do	29 hours.	644	do	Death; sick 72 hours 43 minutes.
569	do	96 hours.			
575	do	24 hours.	647	do	72 hours 21 minutes.
609	do	60 hours.			
583	do	72 hours.			

The average in all the force-fed sheep cases, 25 in number, was 36 hours and 2½ minutes. The minimum was a single observation in Sheep 582, and the maximum was 4 days in Sheep 569. Sheep 569 644, and 647 were very sick, but it is not at all clear that in other

cases the duration of illness was correlated with the severity of the attack.

Of the cattle it should be noted that on 874 and 861 only a single observation was made, so that the sickness can not be considered as continuing an appreciable length of time. Of the other cattle, the average time of duration of illness was 57 hours and 7 minutes, while the shortest period was 30 minutes, and the longest 4 days.

TIME REQUIRED TO PRODUCE SYMPTOMS.

The cattle and two of the sheep were given the Zygadenus in hay, so that the feeding extended over a considerable period of time, and it would be impossible in these cases to determine the time between the feeding and the appearance of symptoms. This can be done, however, in the animals that were given a forced feeding by the balling gun. The following table shows the time elapsed in the case of these sheep.

TABLE 3.—*Time elapsed between feeding of plant and development of symptoms.*

Animal.	Time elapsed before symptoms appeared.	Animal.	Time elapsed before symptoms appeared.	Animal.	Time elapsed before symptoms appeared.
1919.		1920.		1921.	
Sheep Nos.:		Sheep Nos.:		Sheep Nos.:	
528	3 hours.	593	5 hours 30 minutes.	582	4 hours.
530	1 hour 47 minutes.	599	3 hours.	612	4 hours 44 minutes.
555	2 hours 33 minutes.	602	Do.	617	2 hours 5 minutes.
540	2 hours 12 minutes.	609	55 minutes.	628	50 minutes.
		609	3 hrs.	629	1 hour 38 minutes.
1920.		569	2 hours 15 minutes.	644	1 hours 42 minutes.
Sheep Nos.:		575	4 hours 30 minutes.	647	2 hours 2 minutes.
583	22 hours 7 minutes.	609	8 hours 40 minutes.		
590	3 hours.	583	2 hrs.		

The time elapsing varied between 50 minutes in the case of Sheep 628, and 22 hours and 7 minutes in the case of the first experiment with Sheep 583. In this case, however, it is probable that the time is very much too long, because no observation was made upon the animal from 4.47 p. m., June 21, to 9.22 a. m., June 22. It is to be presumed that the animal was sick during the night. Excluding this animal, the maximum time elapsing was 8 hours and 40 minutes, in the second poisoning case of Sheep 609. Excluding, too, the case of Sheep 583, the average of all these sheep cases was 2 hours and 58 minutes.

TOXIC AND LETHAL DOSAGE.

It is evident that a number of factors may affect the toxic dosage of any plant. Most prominent among these factors are the method of feeding, the age of the plant, the part of the plant used, and the kind of animal used for experimental purposes. Any figures in regard to dosage may have a considerable margin of error, as very few animals are subject to experiment under exactly the same conditions.

Effect of method of feeding.—Two methods of feeding were used with the experimental animals, forced feeding with the balling gun and feeding the plant mixed with hay.

Only two sheep, Nos. 564 and 578, were made sick by feeding the plant with hay. They were fed leaves, stems, and buds. The smallest effective dose of leaves, stems, and buds when fed by the balling gun, is 1.096 pounds. The smallest dose of the two animals fed in hay was 0.284 pound in the case of Sheep 564. Apparently the animals fed with hay were made sick on a smaller dosage. There is some doubt, however, in regard to the accuracy of the dosage figures in the case of Sheep 564. Five head of cattle were given the plant in hay, with a minimum dosage of 0.264 pound.

Influence of age of the plant.—It was at first thought that the collections early in the season were somewhat more toxic than those obtained later. A careful examination of the cases, however, does not bear this out. So far as present evidence is concerned, then, the plant is nearly equally toxic at all seasons.

Comparative toxicity of parts of the plant.—An examination of the dosage (Table 1) shows very clearly the extreme toxicity of the seed. The fruit heads stand next, while there is no evidence to show any material difference in the toxicity of the other parts of the plant. It should be stated, however, that of course the weight of seed is of dry material, while the weights of the other parts of the plant are of green material. It would follow, then, that the difference between the toxicity of the seed and the other parts of the plant is not so great as the table indicates.

Effect on different animals.—Only two classes of animals, cattle and sheep, were used in these experiments, and most of the sheep were fed by the balling gun. Comparing Cattle 861 and 863, which received leaves, stems, and young fruit, with Sheep 583, 590, 599, 602, and 605, which were made sick on similar material, it appears that the plant is about twice as toxic for cattle as for sheep. This, if true, is an interesting fact, but probably not of any especial practical importance, as there is no reason to think that cattle on the range eat much of this plant.

As a general statement regarding the toxicity of *Z. paniculatus* it would probably be safe to say that, excluding the fruit and the seed, the toxic dose of the plant is between 1 and 2 pounds per hundredweight of animal.

Fleming [3] gives as minimum toxic doses for yearling calves three-eighths of a pound, and with regard to sheep states that less than one-fourth of a pound rarely produces poisoning symptoms, and in a

[3] Annual Report of the Board of Control for the fiscal year ending June 30, 1919. Agricultural Experiment Station, University of Nevada, Department of Range Management. 1920, pp. 42–43.

few cases over 1 pound has been fed with negative results. Sheep most frequently have been made sick with amounts in excess of 1 pound, while most of the deaths have resulted from 1¾ to 4 pound feedings. Fleming does not give the weights of the animals. If it is assumed, however, that his sheep weighed 100 pounds each, his figures for sheep would not differ widely from those obtained by us. If his yearling calves were well grown, his figures for cattle would be much smaller than those in this paper. In any case, he seems to have found the plant much more toxic for cattle than for sheep, thus far confirming the apparent result of the work reported here.

Toxic dose of Z. paniculatus compared with Z. gramineus.—It is difficult to make anything like an exact comparison of the present results with those given in Bulletin 125 for *Z. gramineus*, because the experiments on *Z. gramineus* were not very carefully checked up with regard to loss of moisture. The *Z. gramineus*, however, was ordinarily used fresh, so that this difference is not so great as it otherwise would be. In the case of *Z. paniculatus*, as quoted in the bulletin, the material used was several days old, and without doubt the dosage would be multiplied by four to bring the figures to green weight. As compared with *Z. gramineus*, the seeds and fruit heads of *Z. paniculatus* are fully as toxic, but the other parts of the plant are much less toxic. The work with *Z. gramineus* showed that in a general way the toxic dose was about 0.5 pound, while the work with *Z. paniculatus*, as stated above, indicates that in a general way the toxic dose is between 1 and 2 pounds, or it may be said that *Z. gramineus* is approximately three times as poisonous as *Z. paniculatus*.

Lethal dosage.—Only one death occurred during the experimental work with *Z. paniculatus*, that of Sheep 644, on 2.5 pounds, and this animal suffered from pneumonia. That it will and does kill under range conditions, however, is abundantly proved by many well-authenticated cases.

LOSSES FROM Z. PANICULATUS.

The stockmen, of course, make no distinction between the species of death camas. Moreover, the systematic botanists are by no means agreed as to the determination of species or the names which should be applied to them. This confusion makes it difficult to state definitely whether reported losses from death camas should be ascribed to one species rather than another. From the distribution of *Z. paniculatus*, as given on page 3, it may be assumed that most of the death-camas losses in Utah, Nevada, Idaho, and eastern Oregon are caused by this species. These losses have been very heavy.

ZYGADENUS ELEGANS.

DESCRIPTION AND DISTRIBUTION OF THE PLANT.[4]

Zygadenus elegans, shown in Plate III, is an erect perennial herb with leafy stems arising from coated bulbs. Often numerous bulbs are together, forming clumps; three are so grouped in the picture. The linear grasslike leaves are one-sixth to one-half inch broad, 4 to 12 inches long, and are much whitened, particularly when young; the lower ones are sheathing at base, the upper without sheaths.

The flowers are in racemes which are simple or somewhat branched below, and often few-flowered. Under the flowers are ovate-lanceolate purplish bracts. The greenish straw-colored or whitish flower segments are one-fourth to five-twelfths of an inch in length and adhere to the base of the ovary. The glands of the upper flower segments are obcordate. The ovary is ovate in form and the stamens are included.

FIG. 5.—Distribution of *Zygadenus elegans* in the western part of the United States.

In the western part of the United States (figure 5) this plant ranges from the Olympic Mountains, Washington, east to central Montana and southward through central Oregon and central Nevada to southern Arizona and east to central New Mexico. In this region it is a high-mountain plant ranging from 2,500 to 13,000 feet. The natural habitat of *Z. elegans* is moist meadows and springy places from the yellow-pine to the arctic-alpine zones. Near the Salina Experiment Station the plant buds early in July, is in flower from the middle of July, and seeds in August and September.

Distinction between Z. paniculatus and Z. elegans.—The technical description already given will serve to distinguish clearly the two species treated of in this bulletin. The stockman, however, using the country within the range of these plants, can readily separate

[4] The description of *Z. elegans* and its distribution was prepared by W. W. Eggleston, of the Bureau of Plant Industry, U. S. Department of Agriculture.

ZYGADENUS ELEGANS. THREE PLANTS GROWING TOGETHER. THE DRIED STEM OF THE PLANT OF THE PRECEDING YEAR IS ALSO SHOWN.

them by their general appearance and habits. *Z. paniculatus* has thick, spreading leaves, while *Z. elegans* has thin, grasslike leaves. *Z. paniculatus* grows in dry, somewhat exposed places at elevations not exceeding about 8,500 feet. *Z. elegans* grows in damp places in meadows, or along small streams, sometimes actually in the water, at others on shady, damp hillsides, and generally in the western mountains at elevations above 8,000 feet. So far as the western ranges are concerned, *Z. elegans* might be called the mountain camas.

EXPERIMENTAL FEEDING.

Experimental feedings of *Z. elegans* to sheep were made in the summers of 1915, 1917, 1918, 1920, and 1921. No definite results were obtained in 1915 and 1918. It appeared later that the dosage in most of these cases was too small to produce intoxication. Inasmuch as during these two years exact data regarding loss of moisture in the plants used were not recorded, the results can not be compared with those of 1917, 1920, and 1921, and it seemed best not to include these experiments in the summarized statement of Table 6. In 1917 there were 11 experimental feedings of sheep, 8 animals being more or less affected. In 1920 there were 21 experimental feedings, resulting in 9 cases of poisoning and 1 death. In 1921 there were 8 feedings, with 2 cases of poisoning. Table 6 gives a summarized statement of the cases of these three years.

TABLE 6.—*Summary of feeding experiments with Zygadenus elegans at Salina Experiment Station, 1917, 1920, and 1921.*

Animal.		Date of feeding.	Method of feeding.	Part of plant fed.	Weight of plant estimated as green plant per 100 pounds of animal.	Result.	Date and place of plant collection.	Remarks.
Designation.	Weight.							
Sheep Nos.:	*Pounds.*	1917.			*Pounds.*		1917.	
431	79	July 14	Balling gun	Leaves, stems, and flowers	2.791	Not sick	Nioche, July 13	
450	80.5	July 15	do	Leaves, stems, flowers, and bulbs	3.494	Sick	Manti Forest, July 13	In 2 forced feedings.
441	97	July 16	do	do	2.273	do	do	
445	96 to 90	do	do	Leaves, stems, and flowers	3.72	Symptoms	Yogo Creek, July 15	
444	92 to 85	July 17	do	do	4.792	do	Yogo Creek, July 16	
445	90 to 89	July 20	do	Leaves, stems, flowers, and bulbs	3.674	Sick	Between Yogo and Nioche, July 19.	
456	100 to 83	July 24	do	Bulbs	2.205	Not sick	Between Yogo and Nioche, July 23.	
449	86.5 to 81.5.	July 25	do	Leaves, stems, and flowers	5.097	Symptoms	do	
455	98 to 89.5	Aug. 1	do	do	5.625	do	Between Yogo and Nioche, July 31.	
455	98 to 89.5	Aug. 2	do	do	2.475	do	do	
453	98.5 to 97.5.	Aug. 2 to 8	Fed	do	16.527	Not sick	Between Yogo and Nioche, July 30.	
		1920.					1920.	
567	91.75	July 9	Balling gun	Leaves, stems, and buds	1.984	do	Blackham's Corral, July 8.	In 1 feeding.
571	75.5	July 10	do	do	2.425	Sickness salivation.	do	Do.
574	80	July 12	do	do	1.970	Symptoms	do	In 1 feeding, partially dried plant used.
577	88	July 14	do	do	2.866	Not sick	Blackham's Corral, July 13.	In 1 feeding.
580	73.25	July 15	do	do	4.555	Symptoms	do	Vomited.
585	75.5	July 16	do	do	3.832	do	do	In 4 feedings. Nausea.
588	101.25	July 19	do	Leaves, stems, and flowers	2.939	Sick	Salina Experiment Station, cattle pasture, July 19.	In 9 feedings in 3 hours; plants in full bloom.
599	96.5	July 23	do	do	6.153	Death	do	In 6 feedings; plants in full bloom.
604	130	July 29	do	do	3.431	Slight sickness.	Cattle pasture, July 26	In 5 feedings.
564	100	Aug. 6	do	Leaves and stems	3.748	do	Cattle pasture, Aug. 5	Flowers and fruits, heads removed; in 4 feedings.
588	105	Aug. 31	do	Fruit heads	0.661	Not sick	Sheep Hollow, Aug. 30.	Plant nearly ripe.
591	123	Sept. 2	do	do	1.009	do	Sheep Hollow, Aug. 31.	In one feeding.

601	105	Sept. 7	do	Pods and seed	0.840	do	Sheep Hollow, Sept. 4.	Pods fully developed. The feeding included the pods and seed from the equivalent of 500 grams of fruit heads per 100 pounds of animal.
594	114	Sept. 9	do	Fruit heads	2.437	do	Sheep Hollow, Aug. 25.	One feeding, pods three-fourths developed; fed dry.
600	94.5	Sept. 10	do	do	2.205	do	Sheep Hollow, Sept. 9.	In 2 feedings.
606	109	Sept. 13	do	Ripe seed (dry weight)	0.187	do	Sheep Hollow, Aug. 30.	In 1 feeding; fed dry; weight given is dry weight.
578	105	Sept. 15	do	do	0.331	do	do	Do.
564	108.5	Sept. 18	do	do	0.386	do	do	Do.
569	113.5	do	do	Leaves, stems, and a few pods	3.668	Symptoms	do	In 2 feedings. Seed had been removed.
568	94	Sept. 21	do	Ripe seed (dry weight)	0.496	Not sick	do	In 1 feeding; quantity fed given as dry weight.
580	73.75	do	do	Leaves, stems, and a few pods	4.409	Sick	do	In 2 feedings; seed had been removed.
		1921.						
622	76.5	June 20	do	Seed	0.606	Not sick	Sheep Hollow, Sept. 4, 1920.	Dry weight.
625	73	June 22	do	Leaves and very few stems and buds.	2.205	Sick	Sheep Hollow, June 21, 1921.	
629	106.5	June 23	do	do	1.984	Not sick	do	
628	95.25	June 24	do	Seed	0.772	do	Sheep Hollow, Aug. 3, 1920.	Do.
630	106.5	June 27	do	do	0.807	do	do	Do.
638	70	June 29	do	Bulbs	2.205	do	Sheep Hollow, June 28, 1921.	
633	92	Aug. 31	do	do	2.8	do	Sheep Hollow, Aug. 29, 1921.	
624	92.5	Sept. 6	do	do	3.	Symptoms	Sheep Hollow, Sept. 5, 1921.	

TYPICAL CASE OF SHEEP 588.

In most of the cases the symptoms were neither very acute nor very prolonged. Sheep 588 may be considered fairly typical of one of the more pronounced cases. This sheep was a yearling wether weighing 101.25 pounds at the time of the experiment. It was taken into the corrals for observation on the morning of July 17, 1920. The experimental feeding was commenced July 19, 1920. On account of the large quantity necessary to produce toxic effect, the plant was administered in several doses. At 10.57 a. m. 200 grams of stems, leaves, and flowers of the plant were given. The sheep was somewhat salivated as the result of this feeding, but no further symptoms developed during the administration of the plant. Other feedings were made at 11.15 a. m., 11.37 a. m., 11.51 a. m., 11.57 a. m., 12.06 p. m., 12.22. p m., 1.10 p. m., and 1.20 p. m. At these feedings quantities varying from 100 to 200 grams were given. The feeding in each case occupied about five minutes. All told, the animal received an equivalent of 2.939 pounds of green plants to 100 pounds of animal.

No symptoms were noted until 4.24 p. m. At that time the sheep was regurgitating and frothing at the mouth. The temperature was 102.8° F., pulse 100, respiration 72. At 5.30 p. m. the animal was still badly salivated, and was standing with the hind legs braced back and head held rather high. The respiration was fast and deep. At 5.55 p. m. the animal showed unsteadiness when attempting to walk. There was at this time distinct hyperesthesia; it was startled by sudden noises or by being touched. The condition remained the same during the evening. Observations continued until 10.30 p. m. The salivation continued and the animal was unsteady on its feet, and occasionally, when startled, would fall down but was able to get upon its feet again. At 9.45 p. m. and 10.30 p. m. it was found lying down but got up readily, although its gait when walking was very unsteady.

On July 20, at 7.10 a. m., when observed it was still salivated, was quiet and depressed, but much stronger than the night before. During the day the condition of the animal improved gradually and on the morning of July 21 it was turned into the pasture, as it seemed to have recovered completely.

DISCUSSION AND RESULTS.

SYMPTOMS.

Salivation.—Salivation occurred in all but 2 of the cases. There was evidence of nausea in 6 cases. In some of these cases this was shown by more or less regurgitation. Actual vomiting occurred in 5 animals.

Weakness.—Pronounced weakness was noted in 14 of the animals.

Temperature.—There was no evidence of any effect on temperature. In this connection perhaps it should be noted that none of the animals, with the exception of Sheep 599, were very sick, and few temperature observations were made on this animal.

Pulse.—No effect on the pulse was noted.

Respiration.—Sheep 599, which was very sick and died, had an irregular respiration that at times was labored. Irregular respiration was noted in Sheep 625. In other cases labored respiration was noted.

Trembling and heightened reflexes.—It is interesting to note that 2 animals, Sheep 588 and 599, exhibited hyperesthesia, and one, Sheep 599, showed muscular trembling. These symptoms were noted quite generally in the *Z. gramineus* cases seen in Montana, but were not seen in the *Z. paniculatus* animals.

In general, the symptoms closely resembled those seen in the effects of the other species of Zygadenus, differing only in degree.

DURATION OF SYMPTOMS.

Table 7 shows the time during which the symptoms continued. As in the similar table for *Z. paniculatus*, the time was computed from the first noted symptom to the last observation.

TABLE 7.—*Duration of symptoms.*

Animal.	Duration of illness.	Animal.	Duration of illness.
Sheep Nos.:		Sheep Nos.—Contd.	
450	6 hours.	580	5 hours.
441	1 hour.	585	1 observation.
445	do.	588	15 hours.
444	5½ hours.	599	6½ hours to death.
445	10 minutes.	604	20 hours.
449	2½ hours.	564	3 hours.
455	1 observation.	569	Do.
455	do.	580	4½ hours.
571	1 hour.	625	20 hours, 6 minutes.
574	1 observation.	624	11 hours, 19 minutes.

The average time of all the cases was 5 hours and 17 minutes. Sheep 599, which died, was sick 6½ hours. The shortest periods of illness were those in which a single observation was made; the longest was 20 hours and 6 minutes.

As compared with *Z. paniculatus* the sickness was of shorter duration.

TIME REQUIRED TO PRODUCE SYMPTOMS.

Table 8 states the time elapsing between the feeding of the plant and the development of symptoms. In some of these cases repeated feedings were made, so that the administration of the plant extended over a considerable period of time. In Sheep 588, for example, the plant was given in 9 feedings involving a period of 3 hours. The

times given in the table are computed from the time when the feedings were finished.

TABLE 8.—*Time elapsed from feeding to development of symptoms.*

Animal.	Time.	Animal.	Time.
Sheep Nos.:		Sheep Nos.—Contd.	
450	Immediately.	580	Immediately.
441	5 minutes.	585	6 hours.
445	12 minutes.	588	3 hours.
444	28 minutes.	599	8 minutes.
445	Immediately.	604	2 hours, 24 minutes.
449	14 hours, 55 minutes.	564	2 hours, 36 minutes.
455	Immediately.	569	Immediately.
455	do.	580	5 hours.
571	5 hours.	625	10 minutes.
574	7 hours.	624	7 hours, 37 minutes.

In some of the animals the symptoms followed immediately after the feeding. The longest time before symptoms was 14 hours and 55 minutes in the case of Sheep 449. This probably is longer than the actual time, for the symptoms were first noted in the morning and it is probable that the animal had been sick during the night. Excluding Sheep 449 the average time elapsing between the feeding and the development of symptoms was 2 hours and 5 minutes. On the average the symptoms appeared somewhat more quickly than was the case with *Z. paniculatus*.

RESULT OF AUTOPSYS.

Opportunity was found for only one autopsy, that on Sheep 599. In this animal the left ventricle was contracted and the right expanded. The left lung was highly congested, and the right lung congested to the point of hepatization. The extreme condition of the right lung was probably due to hypostasis. No other abnormal conditions were noticed.

TOXIC AND LETHAL DOSAGE.

Table 6 shows the dosage of the animals poisoned in 1917, 1920, and 1921.

To determine the probable toxic dosage of the plant it is necessary, of course, to consider only the minimum quantities required to produce intoxication or death.

It should be noted in connection with this table that although both seeds and fruit heads were used, no results were obtained from the dosage used from these parts of the plant. Sheep 630 received 0.807 pound of seed with no effect, and Sheep 594 received 2.437 pounds of fruit heads with no effect.

So far as Table 6 is concerned, it appears that in general terms the toxic dose of *Z. elegans* varies from 2 to 4 pounds per 100 pounds of animal.

Lethal dose.—Only one animal, Sheep 599, was killed by *Z. elegans*. The quantity used in this case was 6.153 pounds of leaves, stems, and

flowers. Sheep 455 received 5.625 pounds of leaves, stems, and flowers with the result that only symptoms were produced. It seems fair to presume that the lethal dose is about 6 pounds per 100 pounds of animal.

Comparative toxicity of different parts of the plant.—The dosages shown in the table do not give any clear indication regarding the relative toxicity of different parts of the plant. It appears probable, however, that the stems are less toxic than the other parts of the plant, that the bulbs are certainly no more toxic than the other parts, and that the plant is possibly somewhat more poisonous in the bud stage than later in the season.

Probably no cumulative effect.—In 1915 Sheep 334 received for 13 days an average daily dose of 1 pound of leaves, stems, buds, and flowers. The feeding was commenced July 16 and terminated on July 29, when the animal died from choking. The animal was salivated July 17, 19, and 20 and seemed somewhat depressed. These symptoms, however, did not increase in the succeeding days. In fact, after July 20 no symptoms were noticed except slight depression.

In 1919 Sheep 453 received for seven days an average daily dose of 2.361 pounds of leaves, stems, and flowers with no effect. In this same year Sheep 455 received 5.625 pounds of leaves, stems, and flowers on one day and on the succeeding day 2.475 pounds. The sheep exhibited symptoms on both days, but was not seriously affected, although the dose of the first day was very large, and that of the second greater than the minimum toxic dose. These experiments were not numerous enough to form the basis for a dogmatic statement, but they are nevertheless significant, and indicate the probability that there is little, if any, cumulative effect in poisoning by *Z. elegans*.

Comparison of dosage with that of Z. elegans in 1913.—In Bulletin 125 was reported the poisoning of two experimental sheep at Greycliff, Mont., by *Z. elegans* obtained from the Beartooth National Forest. It was stated that Sheep 199 showed symptoms from 0.44 pound of leaves, stems, flowers and some fruit, and that Sheep 185 showed slight sickness from 0.66 pound of leaves, stems, flowers and some fruit. Apparently this is a very much smaller dosage than that in the present work at the Salina Experiment Station. In the experiments with this plant at Greycliff, Mont., however, no account was made of the loss of weight by drying. In all the later work careful drying experiments have been made and it has been found that the plants suffer a surprising loss of moisture in a short time. The Beartooth National Forest material was collected July 20, 1913, and used July 28. We now know that it must have lost at least 75 per cent of its weight in that time, so that if we estimate the dosage in

green weight the figures for the dosage of Sheep 199 and 185 should be multiplied by four. This makes the dosage compare fairly well with the 1920 experiments.

COMPARATIVE TOXICITY OF Z. GRAMINEUS Z. PANICULATUS, AND Z. ELEGANS.

From the somewhat insufficient data of the experimental work there have been tabulated the smallest effective doses in sheep of the three species of Zygadenus which have been examined. All these cases were of forced feedings with the exception of the feeding of seed of *Z. gramineus*.

TABLE 11.—*Comparative toxicity of Z. gramineus, Z. paniculatus, and Z. elegans; minimum effective dosage.*

Part of plant.	Z. gramineus.	Z. paniculatus.	Z. elegans.
	Pound.	*Pounds.*	*Pounds.*
Leaves, stems, and young fruit	0.757	1.505	
Leaves and stems	.33	1.984	3.748
Fruit heads	.141	.62	
Seed	[1].092	.07	
Leaves, stems, and buds	.495	1.096	1.97
Leaves, stems, and flowers			2.939
Leaves, stems, flowers, and buds	.495		
Leaves, stems, flowers, and bulbs			2.373

[1] Fed.

Table 11 shows those cases which received similar material. It is impossible, of course, to determine from a table of this character the relative toxicity of the plants with any degree of exactness. It appears, however, that, put in a general way, *Z. gramineus* is three times as toxic as *Z. paniculatus*, and seven times as toxic as *Z. elegans*. It is interesting to note that, so far as the experiments are concerned, the toxicity of the seed of *Z. gramineus* and *Z. paniculatus* is practically the same.

COMPARATIVE TOXICITY OF FRUIT AND SEEDS OF Z. PANICULATUS AND Z. ELEGANS.

Ripe fruit heads of both *Z. paniculatus* and *Z. elegans* were collected and the seed separated from the pods and weighed. In both species it was found that very close to one-half of the dry weight was seed. In one collection of nearly ripe *Z. elegans* the fruit heads were weighed separately from the rest of the plant and found to be 23.4 per cent of the entire plant exclusive of the bulbs and roots. From this it appears that in *Z. elegans* close to 11.7 per cent of the weight of mature air-dried plant is seed.

The comparative toxicity of fruit heads and seed of *Z. paniculatus* shows that most of the toxic element of the fruit heads is in the seed. Sheep 569 was made very sick on 0.661 pound of green fruit heads, a sample of which lost 77 per cent in drying. This, then, was equivalent to 0.152 pound of dry material. Sheep 609 was made sick on 0.124 pound of dry fruit heads. Sheep 583 was made very sick on

0.07 pound of seeds, or almost exactly one-half the dose of the whole fruit head.

Drying experiments make it possible to figure the doses of various parts of the plant given in terms of dry material. Inasmuch as the seeds fed were dry, this is desirable in making comparisons of relative toxicity of seeds and other portions of the plant. When this is done it appears that with *Z. paniculatus* the seeds are twice as toxic as the fruit heads and four times as toxic as leaves, stems, and flowers, while the fruit heads are about twice as toxic as leaves, stems, and flowers. That this ratio does not hold with *Z. elegans* is shown by the feeding of 0.463 pound of dry fruit heads and 0.807 pound of seed without effect when 0.623 pound was found to be a toxic dose of dry leaves, stems, and flowers. In other words, fruit heads or seeds of *Z. elegans* are little if any more toxic than leaves, stems, and flowers.

Z. ELEGANS NOT ESPECIALLY DANGEROUS FOR SHEEP.

If sheep were to graze on *Z. elegans* they would rarely get the bulbs, although these can sometimes be pulled up, as the plant grows in wet ground and the bulbs are not far from the surface. The feeding would be largely on the aerial parts of the plant, and of these it is thought that the fruit and seeds would seldom be eaten, as they are dry and unattractive. Of the parts of the plant likely to be eaten it would take from 1.5 pounds to between 3 and 4 pounds per 100 pounds of animal to poison an animal and 6 pounds to produce a fatal effect. It follows that poisoning from *Z. elegans* is not likely to occur, as sheep would seldom eat so large a quantity. Moreover, *Z. elegans* grows in localities where there is ordinarily an abundance of vegetation, so that animals would not be forced to eat it because of a lack of other forage. While both *Z. gramineus* and *Z. paniculatus* may and do cause losses, *Z. elegans* can be hardly be reckoned as an important poisonous plant; in fact, it is doubtful whether it causes any losses on the range.

SUMMARY.

1. In preceding investigations of the species of Zygadenus, known popularly under the collective name of "death camas," little attention has been given to the comparative toxicity of the various species.

2. Detailed studies of *Z. paniculatus* and *Z. elegans*, compared with preceding work with *Z. gramineus*, have shown a marked difference in toxicity.

3. *Z. paniculatus* is found to be about one-third as toxic as *Z. gramineus*, and *Z. elegans* about one-seventh.

4. While *Z. paniculatus* is not so toxic as *Z. gramineus*, it is a distinctly dangerous plant, and is the cause of heavy losses of livestock. *Z. elegans*, however, while it may poison livestock, probably does little or no damage under practical range conditions.

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